National Aeronautics and Space Administration

NASA's Marshall Space Flight Center

Launching the Future of Human Space Exploration and Scientific Discovery

NASAfacts

Engineers and scientists at Marshall Space Flight Center in Huntsville, Alabama, have pioneered the design of rocket engines, launch vehicles, space systems, science instruments and payloads that make possible unprecedented human and robotic missions. Today, Marshall is essential to ensuring our nation can send humans beyond Earth's orbit and into deep space on bold new missions of space exploration.

Marshall is leading development of the Space Launch System, the most powerful rocket ever built to carry human explorers, cargo and science payloads farther into space than ever before, including a journey to Mars. Marshall also manages the Michoud Assembly Facility in New Orleans, where the giant core stage of SLS is under construction by teams with unique expertise and leading-edge tools, including the largest spacecraft welding tool in the world — the 170-foot-tall, 78-foot-wide Vertical Assembly Center.

Since Marshall's establishment in 1960, its engineers, researchers and scientists have always played a critical role in human space exploration. Marshall designed, built, tested and helped launch the massive Saturn V rocket that carried astronauts on the Apollo missions to the moon and developed new rocket engines and tanks for the fleet of space shuttles. Sections of the International Space Station were built by Marshall, where teams in the Payload Operations and Integration Center work 24/7 with astronauts and manage all of the unprecedented science studies conducted aboard the station.

Marshall enables scientific discovery and deeper understanding of the cosmos through development and testing of sophisticated unmanned spacecraft, hardware and instruments for many projects, including NASA Great Observatories such as the Chandra X-ray Observatory, Hubble Space Telescope and the new James Webb Space Telescope, scheduled for launch in 2018.

One of NASA's largest field centers, Marshall has more than 2,300 civil service employees, a total workforce of nearly 6,000 and an annual budget of approximately $2 billion.

Space Launch System Development

The future of space travel is evolving as NASA creates new launch and spaceflight vehicles that will provide the capability for crewed exploration and science missions beyond low-Earth orbit and into deep space. The Space Launch System, which began development in September 2011, is America's new, heavy-lift vehicle and will be

An artist's rendition of NASA's Space Launch System ready for a night launch. The first SLS test flight is scheduled for 2018.

the most powerful rocket ever built. SLS is the only rocket with the power to send humans, the landers and habitats they will need to explore deep space, and high-priority science payloads on new missions beyond Earth orbit, providing unprecedented opportunities for discovery. The evolvable SLS design leverages investments already made in proven launch systems while also incorporating the latest technology advancements.

The initial SLS configuration, called Block 1, will have a lifting capacity of 70 metric tons (77 tons). The next planned upgrade of SLS, Block 1B, will use a powerful exploration upper stage for more ambitious missions with a 105-metric-ton (115-ton) lift capacity. In each configuration, the massive rocket will use a liquid hydrogen and liquid oxygen propulsion system, relying on four RS-25 main engines for core stage power. Marshall's unique test capabilities and facilities will subject the giant propellant tanks and other elements of the SLS core stage to the stresses they will endure in launch and flight. Dual, five-segment solid rocket boosters — larger and more powerful versions of those used on the space shuttle — will be mounted to the sides of the tank and provide thrust for liftoff and ascent.

A later evolution, Block II, will provide a 130-metric-ton (143-ton) lift capacity for Mars journeys. SLS will provide a safe, affordable and sustainable means of sending explorers beyond Earth's orbit and enable new missions of exploration across the solar system, including a journey to Mars.

NASA intends to launch the first, full-scale test flight of the 70-metric-ton SLS with an uncrewed Orion spacecraft in 2018 — taking another giant step toward sending explorers on deep-space missions of discovery and exploration critical to humanity's progress and prosperity.

International Space Station Support

The International Space Station — the largest and most complex international scientific and engineering feat in history — orbits Earth with its crew every 90 minutes. The first crew began work on board the station in October 2000 — less than two years after launch of the first module — and the station has been continuously occupied by men and women from around the world ever since, conducting research off the Earth, for the Earth.

The Payload Operations Integration Center at Marshall coordinates and integrates all scientific and commercial experiments on the station, as well as Earth-to-station science communications, 24 hours a day, every day of the year. This includes all the unprecedented science investigations of NASA's international partners, including the Russian State Corporation for Space Activities, European Space Agency, Japan Aerospace Exploration Agency and Canadian Space Agency. The payload operations team partners with control centers worldwide to plan, synchronize and monitor science activities and manage the use of valuable on-orbit resources.

With the lifespan of the International Space Station extended to 2024 and possibly beyond, Marshall's development of sustaining station hardware has become even more important. Marshall designed, developed and supports the station's Environmental Control and Life Support System, which eliminates the need for constant restocking of water and oxygen from Earth by filtering and recycling water and air instead of depending entirely on resupply missions. These systems also provide valuable data that will help in the design of state-of-the-art life support for future space-faring vehicles on long-duration missions to deep space, such as a journey to Mars.

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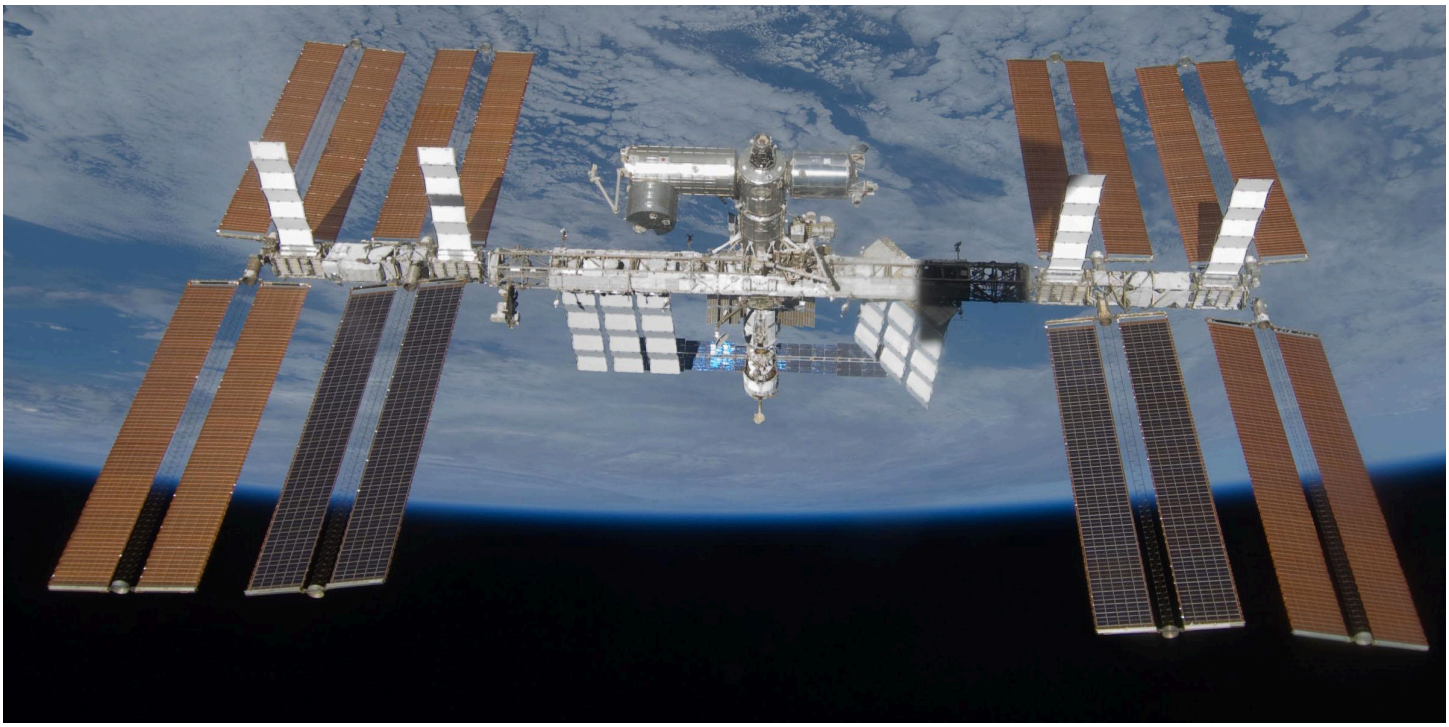


The International Space Station travels more than 17,000 miles per hour, orbiting the Earth 16 times a day.

The Materials Science Research Rack is a refrigerator-sized unit used to contain and run investigations on the station, and is managed by Marshall. Installed on the station in 2009, the facility enables the on-orbit study of a variety of materials, including metals, ceramics, semiconductor crystals and glasses. Many countries have processed a variety of materials in the facility, discovering new applications for existing materials and new or improved alloys which will contribute to the designs of future spacecraft.

Marshall also manages the Microgravity Science Glovebox, an enclosed experiment facility more than 7 feet tall. Its airtight glove portals allow crew members to manipulate hardware and experiment samples without the danger of parts or particulates escaping into the open laboratory module.

The "EXPRESS" Rack — Expedite the Processing of Experiments to the Space Station — is a standardized rack system for transporting, storing and supporting experiments on the station. Designed and managed by Marshall, it enables quick integration of multiple payloads in a streamlined approach, providing a valuable platform for supporting a variety of investigations with the power and data connections they need.

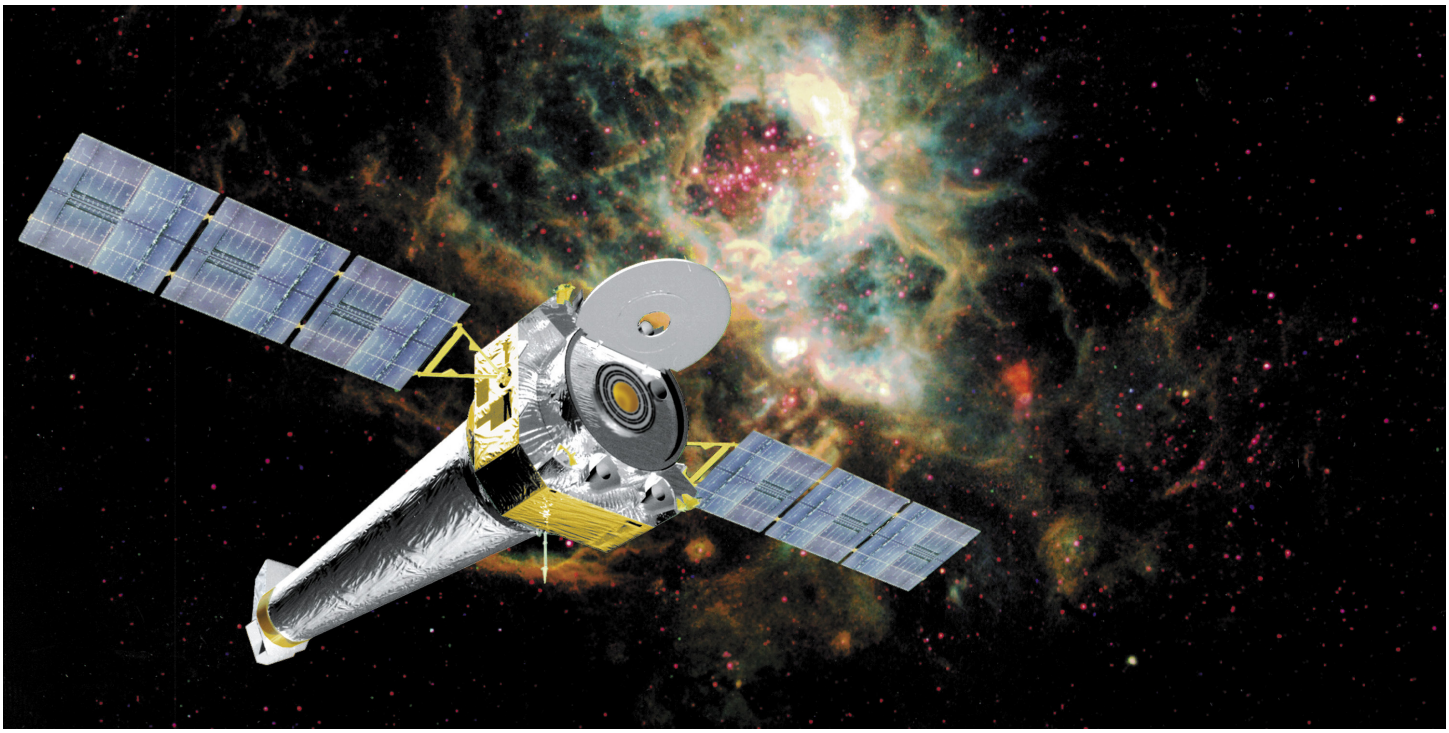
A Marshall-designed Earth science observatory rack provides the space station with an eye in space, helping researchers keep watch over Earth. The Window Observational Research Facility offers an Earth-facing window and rack infrastructure for mounting cameras to capture some of the most detailed images and information about our planet ever documented from an orbiting spacecraft. The rack maximizes use of the highest-quality optical science window ever flown on a crewed spacecraft. Meticulously calibrated before its installation, the window has been used by station astronauts since the Destiny Laboratory module became the keystone of NASA's space station research facilities in 2001.

Exploring the Solar System and the Universe

Scientists at Marshall are conducting a wide spectrum of astronomy, space science, astrophysics and heliophysics research to help answer elusive questions about our solar system and the cosmos—seeking to better understand the universe and our place in it, and working to unlock scientific mysteries that will improve and protect life on Earth.

The world's most powerful X-ray telescope, NASA's Chandra X-ray Observatory, continues to rewrite textbooks with discoveries about our own solar system and images of celestial objects billions of light years away. Chandra, one of NASA's Great Observatories, was designed, developed and constructed at Marshall. It launched in 1999, and has provided new insight into the X-ray universe ever since. Marshall continues to support Chandra science activities, working with the Smithsonian Astrophysical Observatory, which oversees Chandra operations at its facility in Cambridge, Massachusetts.

To see astronomical sources even more energetic than X-rays, Marshall scientists study the gamma ray universe with the Fermi Gamma-ray Burst Monitor, a joint U.S.-



NASA's Chandra X-ray Observatory provides detailed images of heavenly bodies that are billions of light years away.

German instrument aboard the Fermi Gamma-ray Space Telescope, launched in 2008 to study high-energy gamma rays in deep space. In 2013, the Fermi telescope's primary mission was extended by five years.

The X-ray & Cryogenic Facility at Marshall was used to conduct cryogenic vacuum-chamber testing for the James Webb Space Telescope. Scheduled to be launched to space in 2018, the high-powered Webb telescope will enable researchers to look back in time, studying the earliest formation and evolution of stars and galaxies.

Marshall physicists and engineers not only devise instruments to study faraway stars, but also design instruments and fly missions to help us learn more about our own star, the sun. Marshall developed scientific instrumentation and manages science operations for the international Hinode mission, launched in 2006 to investigate the interaction between the sun's magnetic field and its corona.

Marshall combined solar science expertise with precision engineering craftsmanship to launch the Chromospheric Lyman-Alpha Spectro-Polarimeter, or CLASP, mission in 2015. Its revolutionary, Marshall-built camera documented, for the first time ever in such detail, a specific wavelength of ultraviolet light in the sun's upper chromosphere and transition region, helping the international CLASP team understand the role of that region's magnetic field in generating powerful solar flares and other disruptive activity. Marshall scientists will next examine the sun in detail in 2018, when NASA launches the Solar Probe Plus mission. It will contain Marshall-built instruments to count and measure the properties of the most abundant particles in the solar wind: electrons, protons and helium ions. The mission will shed new light on the relationship between the sun's corona and its magnetic fields and help explain how they generate and accelerate the solar wind, respectively.

Since 2004, Marshall has been home to the program office for NASA's Discovery and New Frontiers programs. The Discovery Program, founded in 1992, tasks researchers with designing and flying low-cost, highly focused planetary science investigations to deepen our knowledge about Earth's solar system. The New Frontiers Program, begun in 2003, seeks to fly mid-sized, cost-effective spacecraft roughly every three years to conduct specialized, high-value scientific studies of the solar system identified as top priorities by the international planetary research community. The OSIRIS-Rex — short for the "Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer" — launched in September 2016. It will reach Bennu, a near-Earth asteroid, in 2018 to take samples for study, and return to Earth in 2023. Strofio, a unique mass spectrometer that will determine the chemical composition of Mercury's surface, is set to fly in 2018 aboard the joint European and Japanese Bepi-Colombo/Mercury Planetary Orbiter spacecraft.

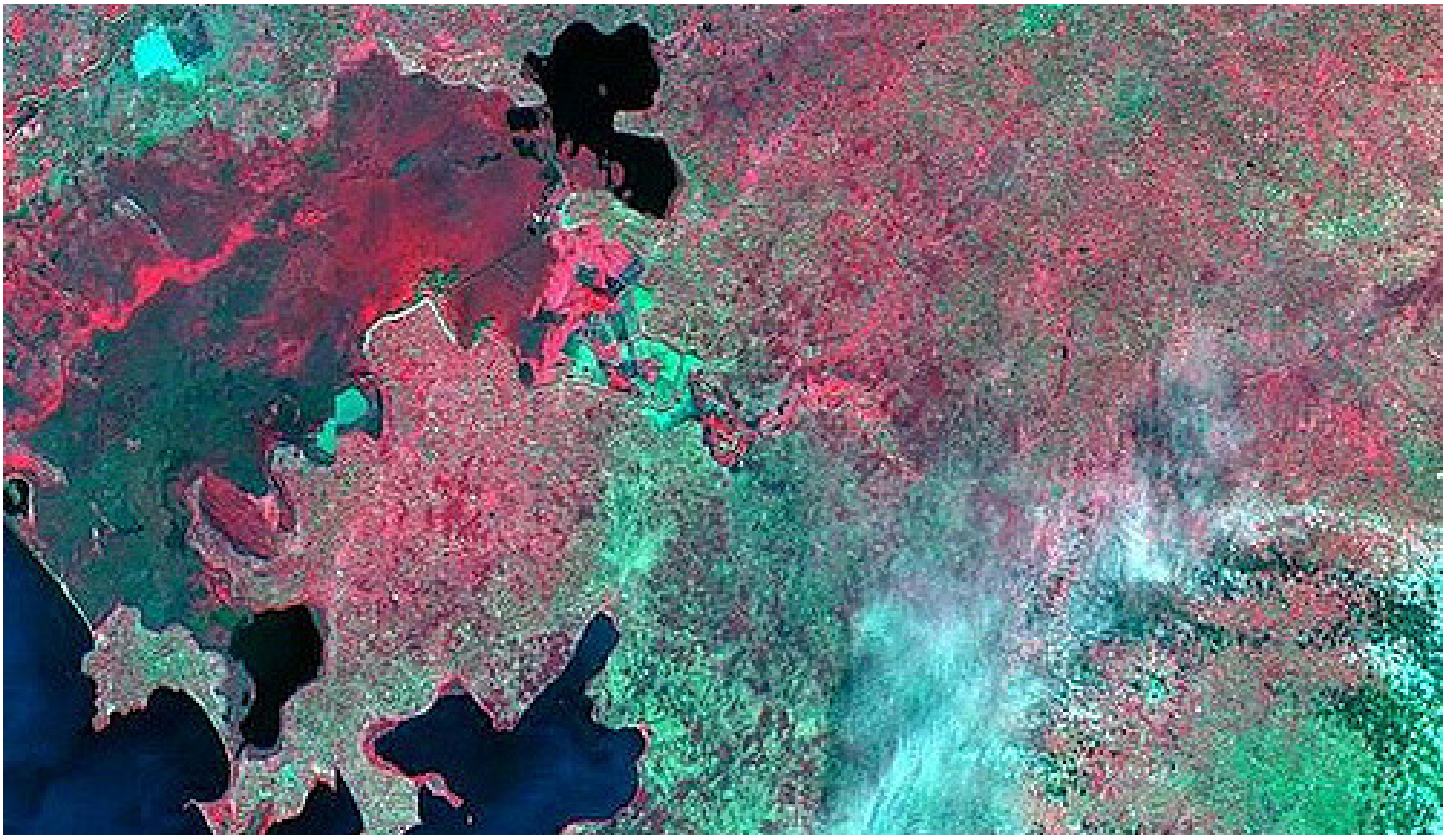
Protecting and Improving Life on Earth

Scientists at Marshall work to improve people's daily lives around the world through discoveries in Earth science. As the planet changes, they're observing, studying the atmosphere, winds, water vapor and minute air particles, temperatures at different altitudes and lightning. Using advanced technologies, Marshall researchers collect and study data from space, air, land and sea to tackle challenges facing the world today, including improved weather prediction, natural resource management and protection of lives, property and resources.

A key Earth science project called SERVIR, which is Spanish for "to serve" — developed and managed for NASA by Marshall scientists — uses a high-tech visualization system that integrates images and data from satellites to monitor the environment around the globe. A joint initiative between NASA and the U.S. Agency for International Development, SERVIR works in partnership with regional organizations in Central America, the Caribbean, Africa, Southeast Asia and the Himalayas to help developing countries use space technologies to address important regional and global issues. SERVIR provides unique knowledge enabling policymakers, government agencies and other stakeholders to make better-informed decisions on critical issues such as climate change, availability of fresh water, food security and human health. SERVIR images and assessments can help speed evaluation of disasters and may improve response times during emergency relief operations.

Marshall's expertise in space and scientific exploration also contributes to essential services provided to the American people by other federal agencies. The NASA Short-term Prediction Research and Transition Center, or SPoRT, provides real-time NASA satellite data and products to the National Weather Service to help improve forecasting and save lives and property.

Marshall often develops new ways to observe Earth's interrelated natural systems and to sustain long-term climate data records. Marshall's newest addition to the sophisticated instruments supporting this work is the Lightning Imaging Sensor, scheduled for launch to the space station in 2017. It will be the first instrument to collect global lightning measurements from the station, providing scientists, decision-makers and governments the world over with consistent, high-quality lightning data, even from the most remote areas. Its observations will provide crucial insight for weather forecasting and studies of climate change, atmospheric chemistry and physics, and could contribute to improved aircraft and spacecraft safety as well.



SERVIR uses space-based data — such as this multispectral image from NASA's Earth Observing 1 satellite of the Nzoia River basin in Kenya — to help regional organizations around the world address issues related to climate change and the management of natural resources.

Engineering the Future

The Engineering Directorate is Marshall's largest organization, providing essential design, test, analysis and operations support to the diverse suite of NASA flight missions, projects and programs expanding humanity's understanding of the universe. Marshall engineers are developing new and advanced technologies and critical knowledge about living and working in space to enable and enhance deep-space exploration. Their work is critical to building and testing NASA's Space Launch System.

Technology created and advanced by Marshall engineers, scientists and researchers is diverse, ranging from new developments in the areas of space transportation and propulsion, to key breakthroughs in space systems and science research. Marshall engineers often leverage breakthrough technologies for multiple purposes. For example, they are pioneering unique 3-D printing or additive manufacturing methodologies to speed development schedules and create more affordable parts for everything from rocket engines to life support systems, and for the in-space fabrication of parts and tools needed on long-duration missions that can't be resupplied from Earth.

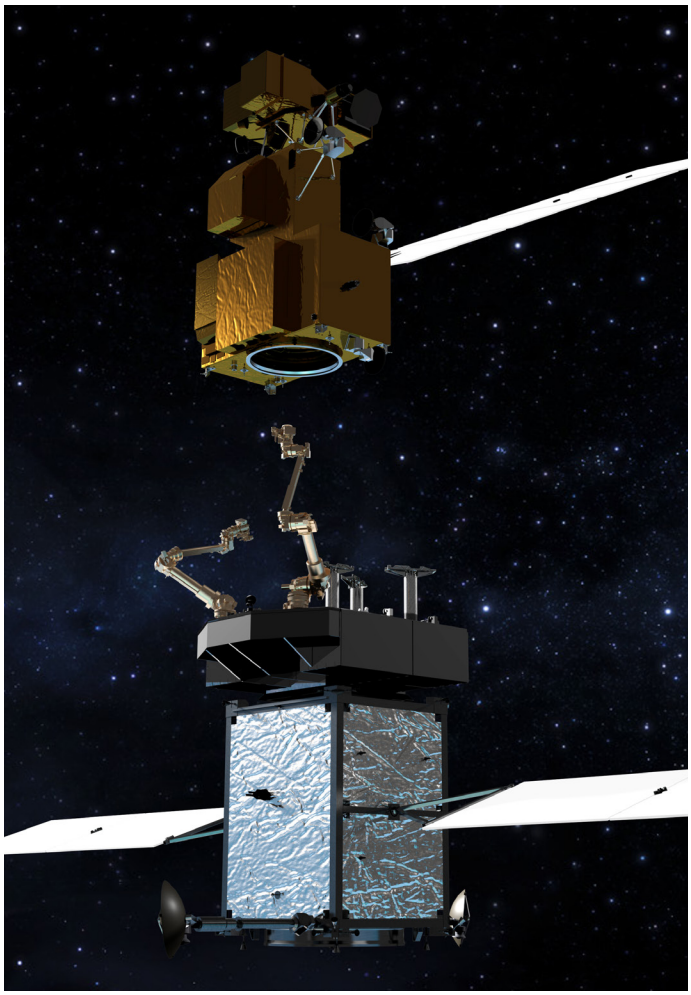
Technology Demonstration Missions

The Technology Demonstration Missions Program, managed by Marshall for NASA's Space Technology Mission Directorate in Washington, is charged with proving innovative, crosscutting technologies that bridge the gap between scientific and engineering challenges and the technological innovations needed to overcome them. These technologies drive exploration, potentially transforming the way human beings live and work in space and travel to and from destinations across the solar system. The program's portfolio of technology demonstration projects — including both ground tests and flight tests — are led by subject-matter experts and top engineering teams at NASA centers and by industry partners around the nation. Each project has the same end-goal: to reduce flight risks, gain operational heritage and enable bolder, more cost-effective and safer missions of science and discovery, continuing NASA's long history as a technological leader.

Centennial Challenges

Centennial Challenges, NASA's technology prize competition program, was founded in 2005 to honor the centennial of powered flight. The program seeks out the brightest and most innovative minds from the public — independent inventors, small businesses, student groups and individuals — to generate innovative solutions for technical problems of interest to NASA and the nation, and provides them with the opportunity to stimulate or create new business ventures. Marshall manages the program for the agency and has hosted several competition events.

Challenges are conducted through unfunded Space Act Agreement partnerships between NASA and nonprofit allied organizations. While NASA provides the prize purse for the competitions, each allied organization is responsible for planning and conducting the challenge, and teams work without government support. Prize challenges may require participants to deliver prototypes that perform according to certain standards; create new methods of solving old technical problems; or accomplish feats that involve the development of new technology or the unprecedented application of existing technology. The program has awarded more than $6.5 million in prize money to teams in 33 competitions covering 11 technology areas, including autonomous robots, rocketry, astronaut glove design and small satellites.



An artist's rendering of the Restore-L servicer craft rendezvousing with a satellite. Restore-L — one of the NASA Technology Demonstration Missions managed by Marshall — will grasp the satellite with its robotic arms, then telerobotically refuel and reposition it.

Michoud Assembly Facility

Marshall manages NASA's Michoud Assembly Facility in New Orleans. The space agency's premiere site for the manufacture and assembly of large-scale space structures and systems, Michoud is one of the largest such facilities in the world, with 43 acres of manufacturing space under one roof.

Approximately 3,000 people are employed on-site, including government and contractor employees and commercial tenants. NASA's primary task at Michoud is manufacturing and assembling some of the largest elements of NASA's Space Launch System and the Orion crew spacecraft. Michoud served as the factory for the Saturn IB and Saturn V first stages for the Apollo moon rockets in the 1960s–70s and the space shuttle external tank, which fueled 135 shuttle flights from 1981–2011.

Michoud offers state-of-the-art manufacturing, fabrication and welding techniques and capabilities, and is home to the National Center for Advanced Manufacturing, a NASA partnership with the state of Louisiana, Louisiana State University in Baton Rouge and the University of New Orleans. NCAM provides the industry with technological leadership and offers advanced building and engineering techniques and expertise.

Providing Real-world Solutions

Thousands of life-saving, life-improving technologies and applications have been derived from NASA research and exploration missions: advanced breast cancer imaging systems, heart pumps, biohazard detectors, water filtration systems and LASIK eye surgery to correct vision are just a few innovations.

NASA's Innovative Partnerships Program, managed at Marshall, works with industry partners to spinoff space technology and adapt it for new applications across many differing industries including medical, communications, safety and transportation.

Leveraging Marshall's unique capability to blend science and engineering, Marshall's Small Business Innovation Research Program and Small Business Technology Transfer Program have contributed to technologies that make possible more affordable drinking water throughout

Welding is completed in the Vertical Assembly Center at NASA's Michoud Assembly Facility in New Orleans on the largest piece of the core stage that will provide fuel for the first flight of NASA's new rocket, the Space Launch System, with the Orion spacecraft in 2018. Standing more than 130 feet tall, the liquid hydrogen tank is the largest cryogenic fuel tank for a rocket in the world.

the world; improve wound healing and relieve chronic pain for soldiers and civilians; and provide artificial intelligence-based technology to improve tutoring programs.

Marshall was awarded NASA's 2016 Small Business Administrator's Cup, recognizing its Small Business Program in promoting the participation of small businesses in helping NASA achieve its goals in fiscal year 2015. Marshall has previously won this award for its small business efforts in fiscal years 2008, 2010, 2012 and 2014.

Education Initiatives

Marshall leads and participates in numerous NASA education projects and activities to engage and inspire new generations of scientists, engineers and explorers, most notably the annual NASA Human Exploration Rover Challenge, a competition originally inspired by the Apollo-era lunar rovers and now inspiring future astronauts for the journey to Mars. Since the first race more than 20 years ago, thousands of students worldwide have designed, built and raced human-powered rovers on simulated lunar and/or Martian terrain. Marshall also leads NASA Student Launch, an annual research-based, competitive activity to provide relevant, cost-effective research and development of rocket propulsion systems. Since the competition was founded in 2001, more than 5,200 American students from middle and high schools, colleges and universities nationwide have designed, built and launched working rockets, complete with science or engineering payloads.

A team of high school students from the Academy of Arts, Careers and Technology in Reno, Nevada, power their away around simulated Martian and lunar terrain during the 2016 NASA Human Exploration Rover Challenge. The annual competition was originally inspired by the Apollo-era lunar rovers and is now inspiring young engineers and scientists to become future astronauts for a journey to Mars.

These and other initiatives, geared toward students and educators alike, enable K-12 and college students to apply their learning to science and engineering projects, and help them gain relevant experience and critical skills and capabilities needed to achieve NASA's continuing missions of discovery and exploration.

More About NASA

New generations of Americans are being inspired each day to ask questions and seek out answers from NASA as the agency blazes new trails to deep space, Mars and beyond. Marshall often partners with other NASA field centers and works closely with the U.S. Department of Defense, Department of Energy, National Oceanic and Atmospheric Administration and other government agencies, and with leading academic institutions and industry partners around the world to advance NASA's missions.

For more information about Marshall missions, partnerships and activities, visit:

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NP-2016-10-111-MSFC
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